Program Research Project

ACE IN THE HOLE: FISCHER-TROPSCH FUELS AND NATIONAL SECURITY

BY

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USAWC CLASS OF 2010

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ABSTRACT

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ACE IN THE HOLE: FISCHER-TROPSCH FUELS AND NATIONAL SECURITY

Petroleum is more than a simple natural resource.[1] It has become thoroughly insinuated within U.S. national power at every level. It is essential to the U.S. military, to the U.S. economy, and is an ever-present consideration of U.S. diplomatic efforts. Over the last hundred years, the United States has risen to superpower status with an economy and society so dependent upon a secure supply of petroleum that it has been pronounced a national security imperative.[2] This work will review the historic significance of energy security, the implications of congressional actions in 2005 and 2007, and how a model of domestic Fischer-Tropsch (F-T)[3] JP-8 production can have multiple strategic benefits as a part of the Air Force *Assured Fuels Initiative* in keeping with the 2008 National Defense Strategy.[4]

World War II: When the United States was Energy Independent

In 1940, U.S. oil production comprised over half of the world total and the United States was an oil exporter.[5] In the pre-World War II build up, Royal Dutch Shell developed the ability to produce 100-octane aviation gasoline on a large scale through a technological breakthrough in fuel refining.[6] Shell realized it could produce this fuel from the abundant supply of crude oil and its secure refining facilities in the United States. 100-octane fuel gave many U.S. and Allied aircraft an edge in acceleration and range. Propelled by a supercharged V-12 that could harness the horsepower of 100-octane gasoline, the P-51 Mustang escorted long-range bombers of the U.S. 8th Air Force to hit strategic targets deep in Germany.[7] America's ability to produce aviation fuel at home gave it the ability to reach strategic targets abroad.

Perhaps the most vital strategic target was Germany's petroleum refining and transport infrastructure.[8] At the beginning of the war, Germany relied heavily upon imported petroleum from Ploesti, Rumania to fuel aircraft, tanks and other vehicles. Their reliance upon imported petroleum was a key vulnerability; a weak point within "the taproot of German might."[9] As the Allies' strategic bombing campaign destroyed German refineries and choked imports from Rumanian refineries, Germany relied more upon liquid fuels synthesized from its native coal at their nine Fischer-Tropsch and twelve coal hydrogenation facilities.[10] Synthetic fuel production peaked in the spring of 1944, after which it was identified and targeted by Allied bomber raids.[11] Germany sought to reduce the vulnerability of importing petroleum supplies from abroad by synthesizing aviation and motor fuel from coal at home, but it was too late.

<u>About the Fischer-Tropsch Process</u>

The Fischer-Tropsch process differs from petroleum refining. Refining takes the vegetable soup of petroleum and separates the various hydrocarbon types into distinct groups based upon their boiling temperatures. That is why they are also referred to as petroleum *distillates.* In some cases refining "cracks" longer hydrocarbon chains into shorter, usable chains to achieve specific octane or cetane ranges.[12]

The F-T process takes any hydrocarbon source (coal or natural gas), or carbohydrate source (biomass), and breaks it down to the simple components of carbon monoxide (CO) and hydrogen (H_2). It then uses the CO and H_2 to reform or synthesize the specific hydrocarbon length needed to create the type motor or aviation fuel desired, (see Figure 1).

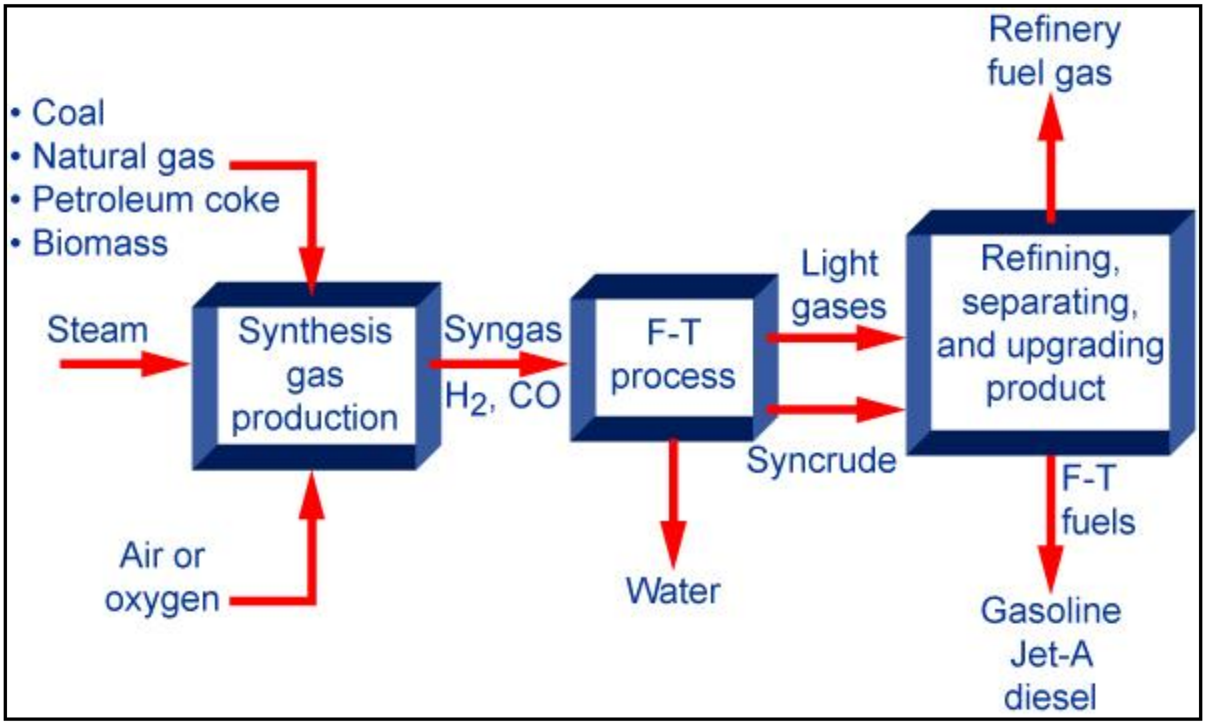


Figure 1. The Fischer-Tropsch Process

Different feed stocks (coal, natural gas, biomass, coke, waste, etc) will break down and yield different concentrations of carbon and hydrogen, often referred to as coal-to-liquids (CTL), gas-to-liquids (GTL), and biomass-to-liquids (BTL) to differentiate the feed stock. Coal is attractive as a feed stock because it brings a heavy concentration of carbon and hydrogen due to its long and complex hydrocarbon chains and its density as a solid. Biomass and pet coke also have heavy concentrations of carbon and hydrogen. Coal, pet coke and biomass also require large capital expenditure for processing equipment (e.g. coal gasification equipment) and removal of contaminants prior to the F-T process.[13] Contaminants such as sulfur can neutralize the catalyst within the F-T process.[14] Natural gas is not as carbon/hydrogen dense as coal but is a convenient feedstock due to its simple molecular structure and has the advantages of already being a gas, thus requiring less capital investment.

Back to Petroleum

As the world found more uses for petroleum distillates throughout the 20th century, demand has increased and so has the breadth of its strategic significance.

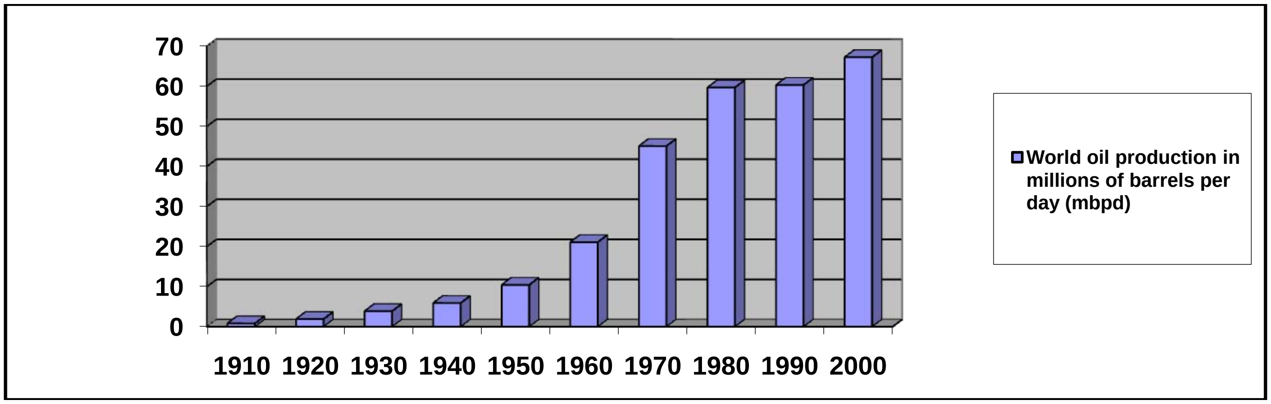


Figure 2. World Oil Production[15]

Three 30-year snapshots illustrate the growth in petroleum's importance. 1) In 1911, First Lord of the Admiralty Winston Churchill made the strategic decision that the British Royal Navy would change propulsion systems from coal-fired to fuel oil.[16] The technology switch to petroleum was a *way* to increase the reach of national power in order to safeguard Britain's global holdings and commerce. 2) In 1941, the Japanese attacked the U.S. Navy at Pearl Harbor and began a war against the United States in the Pacific, in part to secure the oil fields of the Dutch East Indies.[17] In that case, obtaining petroleum was one of the *ends* of national power. 3) In 1973, Saudi Arabia used "The Oil Sword" and enacted an oil embargo against the United States causing a drop in GDP of 3.2%.[18] This effectively elevated petroleum to the equivalent of an economic weapon – a hybrid *instrument* of national power.

Today, U.S. energy independence does not exist. The United States imports well over half of the crude oil upon which its economy is dependent.[19] Dependency is not necessarily a strategic vulnerability in itself. The global economy is based upon mutually dependent and interconnected (inter)national economies. Global commerce runs on interdependence, with petroleum as the dominant fuel of transportation, and with the U.S. dollar as the primary medium of exchange.[20] Broadly, this is good for the United States; thus, safeguarding the global commons is within U.S. national interests.[21] One must dig a little deeper to understand the nature of the threat to current U.S. interests, and why domestic Fischer-Tropsch fuel provides greater security.

<u>The Vulnerability that Imported Petroleum Brings and the Threat to the Global Economy</u>

Within the scope of this work, vulnerability from imported petroleum comes in two forms. One is a large-scale interruption in global supply. The other is economic and political instability from global demand outpacing supply, coupled with sustained high petroleum prices. The first condition is traumatic, but simple. The second is often more gradual, and more complex. In both cases there can be many root causes, but having greater capability to produce fuel at home eases the consequences of either condition, and incrementally lessens international tensions resulting from competitive demand abroad.

As recognized in the 2006 National Security Strategy, "a small number of countries" constitute the world's major petroleum exporters, so a large-scale interruption need only impact a few sources.[22] Worse, much of the oil (and natural gas) exported to the global market passes through maritime choke points, and two are of greatest concern: The Strait of Malacca and the Strait of Hormuz.[23] Asian economies in China, Korea, Japan, Singapore, Taiwan and Philippines import their petroleum through Malacca. Export giants such as Saudi Arabia, Kuwait, Iran, United Arab Emirates and Iraq push their petroleum through Hormuz.

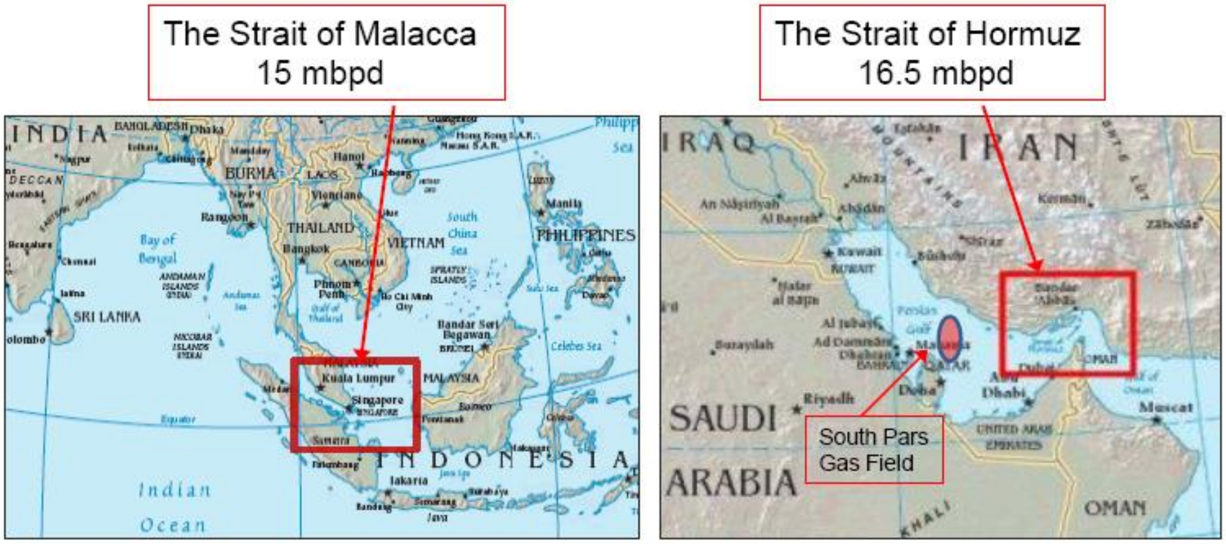


Figure 3. Petroleum Choke Points

Of the approximately 52 million barrels per day (mbpd) of petroleum produced for global export, 15 mbpd passes through Malacca and 16.5 mbpd passes through Hormuz.[24] Well over one quarter of global petroleum export production passes through either (or both) of these two chokepoints every day. The world's petroleum market is global, so a traumatic supply interruption in either of these locations would ripple through all consumer nations. Although not as vital to global commerce as oil, liquefied natural gas (LNG) tankers from Gulf States such as Qatar and Iran also export through Hormuz.[25] Qatar is home to the supergiant South Pars gas field (see Figure 3.), with Royal Dutch Shell's *Pearl* GTL facility and the Qatar/Sasol *Oryx* GTL facility.[26] Both facilities utilize Fischer-Tropsch to synthesize fuels and other distillates from natural gas, and are on course for full scale production.[27]

These choke points are susceptible to interdiction resulting in large-scale supply disruption. The most important is the Strait of Hormuz. Nations surrounding the Persian Gulf and Levant are no strangers to conflict and political instability. Nearly every decade since the 1950s has seen Mideast regional conflict with an impact on petroleum prices, or in some cases embargos.[28] Since the removal of the Saddam Hussein regime in Iraq, the most significant threat to Persian Gulf petroleum has been Iran, as evidenced lately by its 2008 threat to shut down export traffic through Hormuz.[29] Two recent studies by Heritage Foundation (2007 and 2008) measured the long-term economic effects of large scale supply disruption based on a Persian Gulf event.[30] The 2007 Heritage study specifically analyzed the effects of Iran hypothetically taking clandestine military action to shut down the Strait of Hormuz with anti-ship mines.[31]

Using different scenarios, both Heritage studies point to the economic impact upon real gross domestic product (GDP) of the United States, and by inference the global economy. They calculate some of the effects upon international tensions from ensuing economic depression as nations struggle for economic and political survival, but they assume rational and mutually cooperative reactions from various nations. Both studies project a significant contraction of the U.S. economy with the sudden reduction in global supply, bottoming out at over $150 billion dollars of GDP loss per year in either study, with the beginnings of recovery occurring after approximately two years.[32] To give readers a comparison, this approaches the recent economic crisis of 2007-2008.[33]

However, the studies assume reasonable reactions by members of the international community, roughly in accord with International Energy Agency guidelines.[34] Such a cooperative reaction is far from certain. The Russian military incursion into Georgia in August 2008 provides a recent example of how international tensions due to perceived threats to national interests and energy security can result in “muscular intervention” instead of international cooperation.[35] Motivated by a sense of national survival, any nation attempting to secure petroleum reserves by force would further escalate global economic uncertainty. Heritage's modest decline prediction would be a gross underestimation if ongoing conflicts shut down the Persian Gulf for months instead of weeks, resulting in industrial nations such as India and China vying for many of the same petroleum alternatives, as petroleum reserves deplete and with economic survival at stake. If a belligerent nation (or non-state actor) blocks the Strait of Hormuz, the United States will certainly need to take action to neutralize the threat and restore oil and gas flow, but also may need to project significant military power in other regions, such as the Korean peninsula or Venezuela's neighborhood – *or both*. To do so, the U.S. military may need its own assured supply of fuel to bring stability and confidence back to rattled global markets and lines of commerce.

Sudden supply interruption is not the only threat to the United States. Sustained high petroleum prices bring an array of conditions that are adverse to U.S. interests and bring difficulty to U.S. foreign policy. Often, high prices are due to increased demand caused by economic growth, as was the case from 2004 to 2008. The increase in demand was not driven by U.S. economic growth, but by the industrial expansion of China, India and other developing nations. Since 2000, U.S. oil consumption had remained relatively flat (<1% per year) even while the U.S. economy grew at a normal clip, whereas China's growth in consumption has been on a steep rise (>10% per year).[36] With increasing demand outpacing supply, the market responded by increasing price. By the summer of 2008, crude oil had reached an historic high of over $140 per barrel, and gasoline was hovering at $4.00 per gallon.[37] The strong economic growth of several developing nations was a desirable consequence of economic freedom and globalization, but increased competition for energy had adverse side effects.

	Effect	Example
1	Large oil revenues enable exporting nations to adopt policies that oppose U.S. interests and values. Because of their oil wealth, they are free to pursue policies opposed to U.S. interests.	Russia has reverted to authoritarian policies domestically, and conducted military incursions in its near abroad. Russia leverages European oil and gas dependency on key issues in opposition to U.S. interests.
2	Oil dependence constrains the ability of the United States to influence political realignments and to form partnerships to achieve common objectives.	Venezuela uses oil revenue to fund realignment of South America neighbors (Bolivia) against U.S. interests.
3	High prices and perception of scarcity create fears that current systems of open markets are unable to secure tight supplies. Such fears may spur production quotas and price controls, distort true market forces, and thus retard the ability of global trade to restore equilibrium. This brings greater supply shortages and exacerbates international tensions.	In 2008, China central government feared public reaction to rising petroleum costs and the internal instability it might cause. It sought to keep prices down by enacting price controls with its state-run refining arm, Sinopec. Ultimately, this policy created Chinese fuel shortages, rationing and gas lines. It also created tensions between China and other Asian refiners, such as Taiwan and South Korea.
4	High revenues from exports can undermine good governance. Politically weak states have great difficulty when faced with an influx of oil revenues.	Nigeria and Venezuela have been textbook examples of petrostates – states whose governing purpose becomes centered on petroleum profits, not legitimate functions of the state. They are typically unstable and unreliable suppliers.

Table 1. Indirect Adverse Effects of High Petroleum Prices[38]

During times of tight supply, the price is forced upward, and revenues for exporting nations increase with little additional costs incurred. While this is a normal reaction in a free market, the elevated price may create internal and external tensions among consuming nations, and a large influx of revenue for producing nations. When oil exceeds $100/bbl, it pushes a noteworthy amount of revenue into the hands of those running the oil interests in exporting nations.[39]

Table 2. below provides a list of the world's top exporting nations and a comment regarding their stability and reliability. Several exporters in the Persian Gulf were deemed reliable but subject to supply interruption due to their proximity to the Strait of Hormuz. As readers consider the quantities of oil exported, they should consider who is selling it and what other strategic interests the petroleum revenue may be underwriting – Iran and Venezuela, for example.

Rank	**Country**	**Exports** in 1,000 bpd	**Stability/Reliability**
1	Saudi Arabia	8,406	Reliable but subject to supply interruption
2	Russia	6,874	Questionable reliability
3	United Arab Emirates	2,521	Reliable but subject to supply interruption
4	Iran	2,433	Questionable reliability, antipathy to U.S.
5	Kuwait	2,390	Reliable but subject to supply interruption
6	Norway	2,246	Reliable
7	Angola	1,948	Stable in recent years
8	Venezuela	1,893	Questionable reliability, antipathy to U.S.
9	Algeria	1,888	Reliable in recent years
10	Nigeria	1,883	Questionable stability
11	Iraq	1,769	Reliable but subject to supply interruption
12	Libya	1,597	Reliable in recent years
13	Kazakhstan	1,185	Reliable in recent years
14	Canada	1,089	Reliable
15	Qatar	1,085	Reliable but subject to supply interruption
16	Mexico	1,057	Reliable

Table 2. Top Global Petroleum Exporters[40]

Renowned energy historian and consultant, Daniel Yergin has articulated ten principles of energy security to help bring greater stability within the global energy market. Several mitigate the adverse effects of high petroleum prices. Two are most appropriate for the scope of this work: Principles 1 and 9.[41]

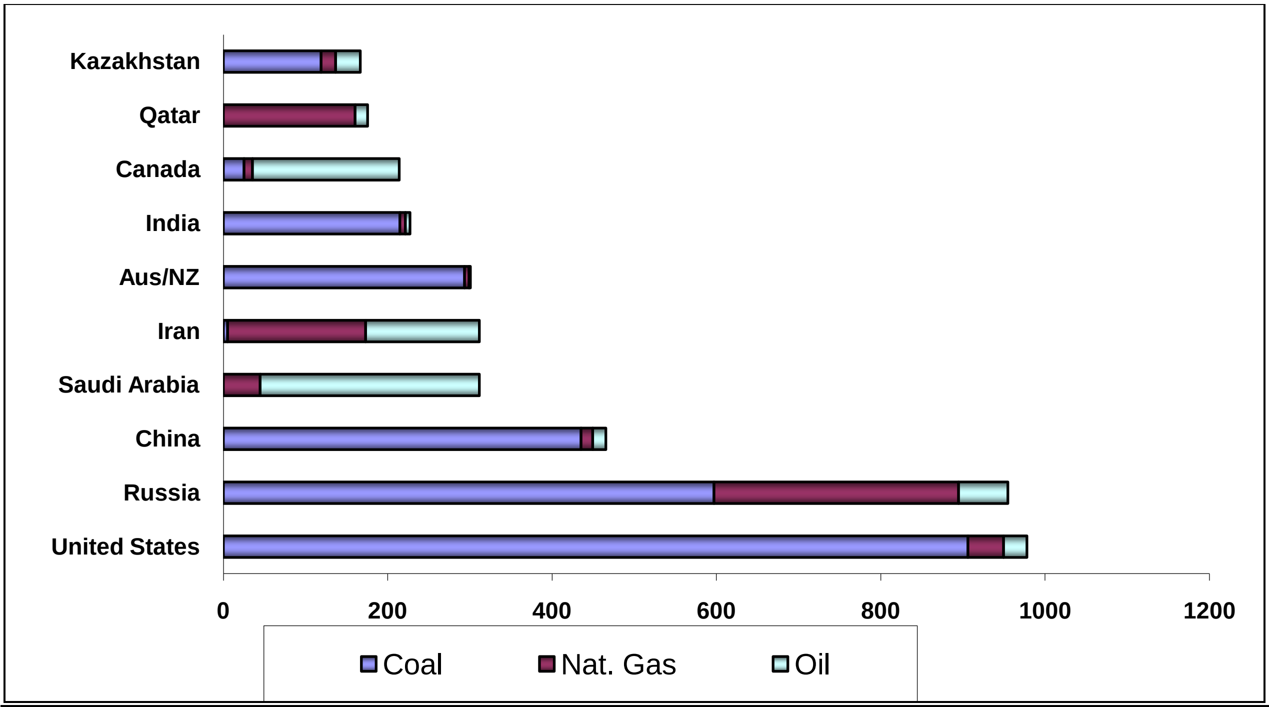
1. Diversification of supply is the starting point for energy security.

9. A technologically-driven energy industry is necessary for energy security.

Having multiple sources of supply reinforces the advantages of a buyer's market. It tends to push prices down and production efficiencies up. Lower energy prices mitigate the excesses of petrostates and tend to drive them toward liberal (and democratic) reforms, if for no other reason than for pragmatism and survival of the governing regime. But the term *multiple sources* should not be limited to simply having multiple oil-producing nations as suppliers. It can also mean multiple forms of supply – or *alternative fuels* provided by a healthy energy industry that yields adaptations and innovations through technological advances. In keeping with Yergin's 1st and 9th principles, and consistent with the 2005 Energy Policy Act, the U.S. Air Force began its Assured Fuels Initiative to assess various forms of alternative fuels and fuel feed stocks. It did not take long for the Air Force to arrive at the option of synthesizing JP-8 from coal and natural gas through Fischer-Tropsch technology.

<u>Coal and Natural Gas: America's Ace in the Hole</u>

It is hard for one to grasp the enormity of U.S. coal and natural gas reserves. Citizens are accustomed to thinking of the United States in terms of an energy importer with declining domestic energy reserves. However, crude oil is not the only potential source of liquid fuel essential to the U.S. economy and the military. U.S. coal reserves are the largest in the world, approximately 50% greater than its nearest competitor, Russia.[42] The United States has been described as the Saudi Arabia of coal, but that is not quite accurate. U.S. coal dwarfs Saudi oil. U.S. coal reserves are equivalent to three Saudi Arabias in terms of the same energy contained in barrels of oil. Further,



	Oil (billions of barrels)	Natural Gas (in trillion cubic feet)	Natural Gas in BOE	Coal (in billion short tons)	Coal in BOE	Total in BOE
Kazakhstan	30.0	100.0	17.7	34.5	119.0	166.7
Qatar	15.2	905.3	160.4	0.0	0.0	175.6
Canada	178.6	58.2	10.3	7.3	25.2	214.1
India	5.6	38.0	6.7	62.3	214.9	227.3
Australia/NZ	1.6	31.2	5.5	85.1	293.6	300.7
Iran	138.4	948.2	168.0	1.5	5.2	311.6
Saudi Arabia	266.8	253.1	44.8	0.0	0.0	311.6
China	16.0	80.0	14.2	126.2	435.4	465.6
Russia	60.0	1,680.0	297.7	173.1	597.2	954.9
United States	28.4	244.7	43.4	262.7	906.3	978.1

Table 3. Total Hydrocarbon Reserves[43]
Graph is depicted in Billions of Barrels of Oil Equivalent (BOE)

coal is not the only alternative. U.S. natural gas reserves have steadily increased during the past ten years with new extraction technologies making tight shale formations now cost effective to drill and produce (see Figure 4).[44] Although less energy dense than coal, natural gas may provide other production flexibilities that make it viable, and thus further diversify sources of supply.

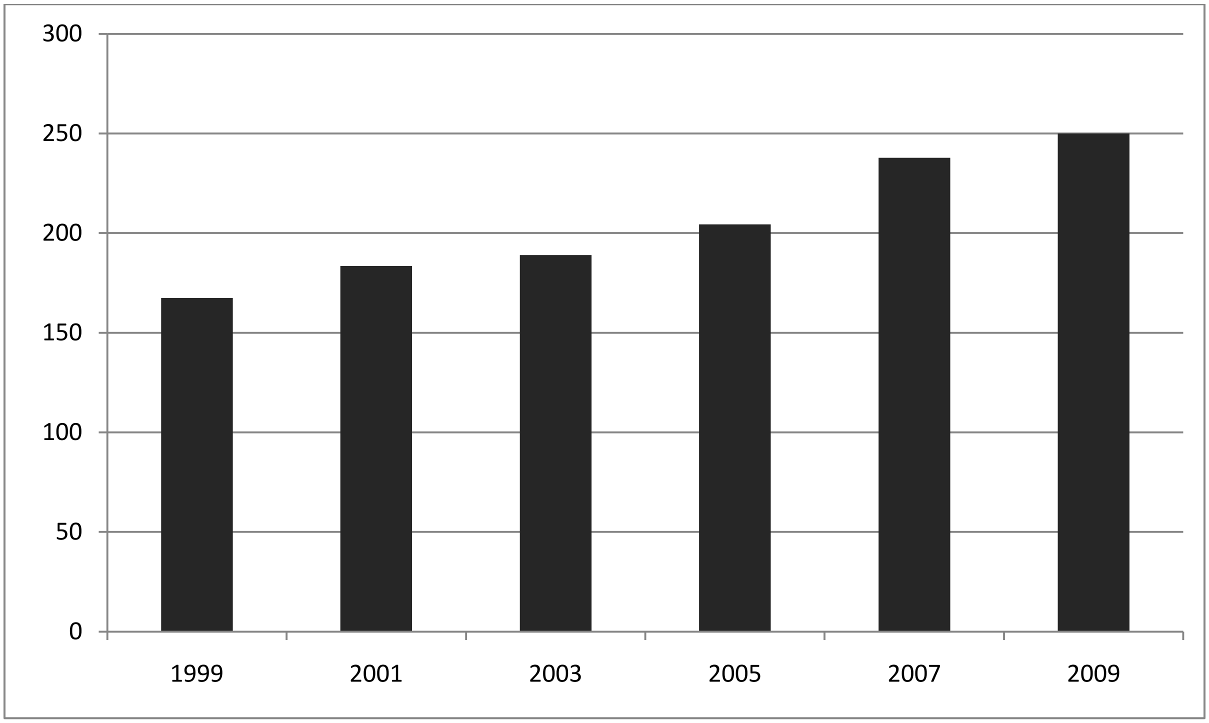


Figure 4. Ten Year Growth of U.S. Proved Gas Reserves
Graph is depicted in Trillion Cubic Feet (tcf)

On the other side of the technology horizon is a form of natural gas called *methane hydrate*. Producing methane hydrate will likely involve much different extraction technologies and equipment due to the unique circumstances of temperature and pressure in which the methane is trapped. The estimated quantity of natural gas available from methane hydrate in the United States is 320,000 tcf. – over 1,000 times the amount of U.S. proved gas reserves in 2009 (320,000 tcf versus 250 tcf).[45] If this amount were posted on the bar graph in Figure 4, it would require a bar measuring 83 meters long. Once extraction technologies are developed, it is a vast domestic source of natural gas that could be used as a feedstock for GTL synthesized JP-8.

Energy Security Policy

For several decades, the U.S. leaders have realized the vulnerability of energy dependency. In 1974, President Richard Nixon sponsored an initiative to wean the United States off of oil imports.[46] In 1977, President Jimmy Carter signed legislation that created the U.S. Department of Energy to help unify U.S. energy policy, and enacted several energy conservation programs such as the federal 55 mph speed limit to lessen U.S. dependency.[47] These efforts and others through the 1980s and 1990s recognized the strategic vulnerability that petroleum dependency brings, complicated by the fact that a fuel supply interruption might inhibit the ability to project military power into regions essential to energy supply.

Awareness of strategic vulnerabilities, coupled with the growing realization of America's abundant unconventional hydrocarbon reserves, spurred Congress to pass the 2005 Energy Policy Act (2005 EP Act). This legislation directed the Departments of Energy, Defense and Interior to develop fuels from unconventional sources:

> United States' oil shale, tar sands, and *other unconventional fuels* [emphasis added] are strategically important domestic resources that should be developed to reduce the growing dependence of the United States on politically and economically unstable sources of foreign oil imports.
>
> –2005 Energy Policy Act, Section 369

From the authority provided in the 2005 EP Act, the U.S. Air Force launched the *Assured Fuels Initiative* which focused on using Fischer-Tropsch synthesis of coal, natural gas, and biomass feed stocks into ultra-clean JP-8 and other needed distillates.[48] This initiative tied directly into the nation's strategic interests of achieving greater energy security and providing safety and stability for U.S. global trade. In the

2006 National Security Strategy, the President stated: “The key to ensuring our energy security is ***diversity*** [emphasis in the original] in the regions from which energy resources come and in the types of energy resources on which we rely.”[49] In the 2008 National Defense Strategy, the Secretary of Defense identified the need to protect the global commons and retain strategic access to important regions of the world. Further, he identified the need to lower dependency on oil, specifically “petroleum products from areas of instability,” and to utilize alternative sources of fuel without detracting from operational capability.[50] In recognition of this strategic necessity, the U.S. Air Force established the goal of using a 50/50 blend of conventional and F-T synthetic JP-8 aviation fuel by 2016.[51]

The Department of Defense (DOD) was well on its way to catalyzing a new energy technology direction with profound strategic and global economic implications. Since the United States had large quantities of coal with established distribution systems and costs, the CTL process was a logical way to start. The Air Force designated land at Malmstrom AFB in Montana to locate a CTL production facility that was close to the massive coal deposits in Montana and Wyoming.

At the same time, the Air Force began testing the 50-50 blend on each airframe, starting with the B-52 in 2006.[52] Private F-T development companies such as Syntroleum provided thousands of barrels of synthetic fuel for the Air Force to test its 50/50 blend on all air frames, as well as ground and air refueling systems. In every test since 2005, the 50/50 synthetic F-T blended fuels have performed the same or superior to conventional JP-8 due to its near-perfect (synthesized) hydrocarbon structure.[53] The synthetic fuel contains no impurities, providing a superior aviation fuel with no sulfur emissions or particulates, and at a projected price under that of JP-8 in recent years.[54]

In 2007, Congress changed course. Due to perceived environmental effects of CO_2 emissions, Congress effectively killed CTL fuel development in the United States with an amendment to the *Energy Independence and Security Act* so that "federal agencies are not spending taxpayer dollars on new fuel sources that will exacerbate global warming".[55] The process of breaking apart hydrocarbons in order to create the syngas precursor to the F-T process also creates substantial amounts of CO_2.[56] Coal and biomass create much more CO_2 than natural gas, so the Air Force has shelved its sponsorship of CTL and hedged its remaining efforts with GTL instead.[57] It is perhaps ironic that Congress has thwarted efforts to develop a fuel source with a proven reduction in known pollutants (sulfates and particulates), in order to reduce a suspected pollutant (CO_2).[58] The change in policy direction by Congress has caused additional delay in implementing an effective alternative fuels program in the United States, but not among emerging industrial competitors such as China.

China has pushed forward with F-T fuel development, in some cases buying U.S. equipment to do so. Sinopec (China Petrochemical Company) bought the Syntroleum F-T processor in Tulsa, Oklahoma, and then moved it to China.[59] Syntroleum's processor made much of the F-T fuels that the Air Force had been testing. China has substantial coal reserves (see Table 3) and has several large CTL facilities under construction, citing energy security priorities over concern about CO_2 emissions.[60] Meanwhile, an independent study by the Rand Corporation and Massachusetts Institute of Technology (MIT) suggests that F-T fuels are cleaner than previously assessed, all things considered, and that Congress' 2007 policy change might bear reconsideration.[61]

Rand/MIT Analysis of Alternative Aviation Fuels

In 2009, Rand Corporation and MIT conducted an analysis on a wide spectrum of alternative fuels with one of the major evaluative criteria being greenhouse gas emissions. Although the analysis was evaluating Jet A (commercial aviation fuel), its characteristics are similar enough to JP-8 to directly correlate the findings.[62] Thirteen different fuel sources were tested, ranging from Jet A refined from Very Heavy Oils (oil sands), biodiesel, ethanol, a full suite of F-T fuels with and without carbon sequestration, and several other fuel types.[63] The Rand study disqualified a few alternative fuels that have attained civilian market share due to stringent performance requirements of aviation fuel. Alternative fuels that are alcohol based are unsafe for high-altitude flight due to high vapor pressure.[64] Biodiesel and biokerosene from various plant oils break down under the high temperatures characteristic of aircraft fuel systems.[65] The study points out that GTL produces approximately 50% lower carbon emissions than CTL or BTL without carbon sequestration, and that "the benefits of ULS [ultra-low sulfur] jet-fuel use in reducing air-quality impact need to be balanced against these potential positive and negative impacts on global climate change."[66] The Rand/MIT study gave a balanced, favorable recommendation for aviation fuels produced from natural gas, given the current regulatory environment regarding CO_2 emissions, cost of CO_2 sequestration and low price of natural gas.[67]

In addition to lower CO_2 emissions, natural gas offers a more convenient feed stock for F-T fuel production. GTL does not require the complex gasification equipment as do coal and biomass. GTL has little waste, and it yields by-products that are all marketable distillates. Depending on the location, GTL facilities can simply tap into existing natural gas distribution infrastructure to purchase methane that requires no additional processing or pre-treatment such as sulfur removal. Thus, GTL facilities can be efficiently built on a smaller scale, both in terms of capital expense and physical footprint.[68]

Total Air Force 50/50 Fischer-Tropsch Blend by Year 2016? Probably Not

The Air Force will probably not reach its self-imposed goal of 50/50 blended F-T fuels as part of the U.S. energy security strategy by year 2016. Congress' change in regulatory policy has halted construction of the big CTL facilities ideally suited for large production in the United States. As an example, the Air Force used nearly 2.5 billion gallons of aviation fuel at U.S. military installations worldwide in 2008.[69] That equates to approximately 60 million barrels of JP-8 (standard 42 gallons per barrel) which would require 30 million barrels of synthetic fuel to blend at a 50/50 ratio. 30 million barrels per year would require non-stop, dedicated production of approximately 82,000 bpd of synthetic JP-8 in order to meet the Air Force's goal.

Rentech Corporation is one of the last remaining companies with an operational F-T unit in the United States. Its demonstration unit in Colorado can produce 250 bpd.[70] Even if Rentech's planned production facility is able to come on-line in 2011 and it scales up production to full capacity of 30,000 bpd, coupled with Syntroleum's anticipated 5,000 bpd Bio-Synfining™ F-T facility, it still leaves a deficit of 48,000 bpd.[71] Overseas, other possible sources include F-T fuels from Sasol's CTL facility in South Africa, its GTL facility in Qatar, or Shell's GTL facility in Malaysia. Barring additional delays, Shell's Pearl GTL facility is scheduled to come on-line in 2011 with production above 100,000 bpd.[72]

The obvious problem with importing from GTL or CTL facilities overseas is that the United States would still be *importing*. It would still be vulnerable to supply interruption. Purchase of such fuels would still be underwriting governments that do not have U.S. interests as paramount. This may be particularly true of synthetic fuels coming from the Persian Gulf regions (Iran is also building GTL capacity).

Small Scale GTL: A Viable and More Secure Alternative

The best solution may be more akin to the German synthetic fuel model of World War II, but for somewhat different reasons. Instead of centralized production, use distributed production. Instead of a new large CTL or BTL facilities, with large environmental concerns and possibly large cost overruns, perhaps ten smaller facilities co-located with U.S. Air Force bases that use appreciable amounts of JP-8 would be better. Instead of using complex feed stock such as coal and or biomass, use simple feed stock such as natural gas that has been processed and can be delivered via existing pipeline. Instead of 50/50 blend of JP-8 for the entire air fleet by 2016 (some 82,000 bpd) perhaps a 50/50 blend for 10% of the fuel consumed at ten U.S. bases by 2015 – a year sooner.

Distributed production of F-T fuels increases flexibility and reliability of the system. Technology upgrades or experimental changes can be accomplished without taking the whole system offline. Best pricing can be enhanced through the competitive power of the consumer – any base commander (or fuels purchaser) can simply compare prices with that of other locations. Most importantly, if the GTL facility can be located on the base, or adjoining it, physical security is enhanced and opportunity for sabotage minimized. In any instance of conventional fuel supply interruption, the United States Air Force will still have 10% of the fuel available at its top ten bases, as long as it has access to natural gas.

Base	JP-8 (gal./yr.)	Base	JP-8 (gal./yr.)
1. McGuire AFB, NJ	69,601,195	6. Barksdale AFB, LA	40,578,964
2. Travis AFB, CA	54,688,084	7. Charleston AFB, SC	40,397,370
3. Altus AFB, OK	51,246,430	8. Seymour-Johnson AFB, NC	36,930,661
4. Nellis AFB, NV	50,166,894	9. Dover AFB, DE	34,552,885
5. Hickman AFB, HI	49,418,313	10. Andrews AFB, MD	33,280,011

Figure 5. Top Ten JP-8 Consumers in U.S.[73]

Using this base data, the capacity to generate enough F-T synthetic fuel to provide a 50/50 blend for 10% of the JP-8 used would necessitate the construction of a GTL processor with an output of less than 1,000 bpd. This is very achievable and affordable. Construction of current generation, small-scale GTL facilities of this size cost about $50,000.00 per barrel of production capacity.[74] So a 1,000 bpd GTL processor would cost approximately $50 million. Ten of them would cost $500 million total, and could easily be constructed within five years.

This compares favorably to the previous estimated cost for large CTL facilities. Each CTL plant was estimated to cost between $1-10 billion and would take up to six years to build.[75] Of course, the production capacity of the CTL facilities was projected to be much greater – up to 80,000 bpd.[76] Undoubtedly, CTL offers many economies of scale that would be desirable to all fuel consumers, once the market is better established. Perhaps the best way to establish that market is with small capacity GTL facilities providing distributed and secure fuel production.

Fischer-Tropsch Fuels: Enabling Power Projection to Safeguard U.S. Interests

The DOD Assured Fuels Initiative should be continued. The Air Force tests of 50/50 blends should keep going until all systems are certified. The Air Force can then put the blended fuels into operation. But without *domestic production* of F-T fuels, for whatever reason, it only benefits many of the same regions from which we currently import oil. Domestic production should be re-established using the ultra-low sulfur nature of F-T fuels to offset the objections of CO_2 emissions.

The United States is not energy poor. It has a card it has not turned – it has an ace in the hole. With proven technology, the United States can utilize its abundant coal and natural gas reserves, and eventually various forms of biomass, to supply substantial portions of needed transportation fuels. To get started with minimal financial and environmental risk, it can establish the use of Fischer-Tropsch fuels from natural gas to provide a modest capability of GTL production of JP-8 at key Air Force bases in the United States.

The United States is limited by its strategic vulnerability due to energy dependency, and it does not need to be. There is nothing wrong with the economic interdependence. It serves as the basis of the global economy and the U.S. has flourished by it. But unlike other trade commodities, energy resources have a unique strategic dimension. Nations with adequate energy have potency. Nations without adequate energy are at the mercy of those that have it. Ultimately, the U.S. military must have the capacity to project and sustain national power anywhere on the globe to safeguard global commerce, to secure strategic regions, and to protect U.S. citizens and sovereignty. Fischer-Tropsch fuels can help provide that capacity.

Endnotes

[1] Daniel Yergin, *The Prize: The Epic Quest for Oil, Money and Power* (New York: Free Press, 1991), 795. The terms "oil and gas," "petroleum," and "hydrocarbons" denote this energy resource. Yergin explains: "By generally accepted theory, crude oil is the residue of organic waste…that accumulated at the bottom of oceans, lakes, and coastal areas. Over millions of years, this organic matter, rich in carbon and hydrogen atoms, was collected beneath succeeding levels of sediments. Pressure and underground heat "cooked" the plant matter, converting it into hydrocarbons – oil and gas."

[2] Jimmy Carter, President of the United States, "State of the Union Address, 1980," 23 January 1980, available from www.jimmycarterlibrary.org/documents/speeches/su80jec.phtml; Internet; accessed 29 January 2010. "Let our position be absolutely clear: An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force."

[3] The Fischer-Tropsch (F-T) process is named after Czech scientists Franz Fischer and Hanz Tropsch for their pioneering work in Germany to convert coal to liquid fuels in the 1920s and 1930s. The process breaks down a hydrocarbon feed stock, such as coal or natural gas, into CO and H_2, and then reforms these constituents into the desired hydrocarbon finished product such as octane (gasoline) or cetane (diesel).

[4] Robert M. Gates, *National Defense Strategy* (Washington, DC: Department of Defense, 2008), 16.

[5] *U.S. Field Production of Crude Oil*, on-line service from Energy Information Agency, U.S. Department of Energy, available from http://tonto.eia.doe.gov/dnav/pet/hist_xls/MCRFPUS1m.xls; Internet; accessed 22 April 2010. In 1940, U.S. production was 4.118 million barrels per day (mbpd) and global production was 5.889mbpd.

[6] Yergin, *The Prize*, 223, 383-384. Catalytic cracking was developed in the 1930s, but required large capital investments to construct new refineries, or to retrofit existing refineries that utilized simple thermal cracking. Catalytic cracking uses heat, pressure *and a catalyst* (e.g.: a liquefied zeolite powder) to reduce long complex hydrocarbon molecules into shorter chain distillates such octane (or cetane). Royal Dutch Shell gambled that the necessity for 100-octane aviation gasoline would cost justify the huge capital investment in research and new refining equipment. Other companies soon followed. With a rapid expansion in catalytic cracking capacity, U.S. oil refining companies such as Cities Service, Jersey Oil, Phillips Petroleum, Shell and others provided over 90 percent of the 100-octane aviation fuel needed for WWII. For more information see: "Industrial Processes in the Petroleum Refining Industry," Michigan State University online curriculum, PRM 255, available from https://www.msu.edu/course/prm/255/ petroleumindprocess.htm; Internet; accessed 22 April 2010.

[7] Michael Sundsig-Hansen, on-line website for historic Spitfire history of British and Free-Danish squadrons, available from http://www.spitfire.dk/Chapter5.htm; Internet; accessed 22 April 2010. The Spitfire and the Mustang were powered by a supercharged Rolls Royce Merlin V-12 (or the Packard variant). This engine burned 100 octane fuel, compared to German

aircraft burning 87 octane fuel, giving Allied fighters an often decisive edge with bursts of horsepower during dogfights. The P-51 was made famous by its long range and its rapid acceleration.

[8] Albert Speer, German Minister of Armaments, *Inside the Third Reich*, trans. Richard and Clara Winston (New York: Macmillan, 1970) as quoted in Yergin, *The Prize*, 346.

[9] Winston Churchill as quoted in James Dugan and Carroll Stewart, *Ploesti: The Great Ground-Air Battle of 1 August 1943* (New York, NY: Random House, 1962), 29.

[10] Anthony N. Stranges, “Germany’s Synthetic Fuel Industry, 1927-45,” Presentation at the American Institute of Chemical Engineers 2003 National Meeting, March 30 - April 3, 2003, available from http://www.fischer-tropsch.org/primary_documents/presentations/AIChE%202003% 20Spring%20National%20Meeting/Paper%2080a%20Stranges%20germany.pdf; Internet; accessed 29 April 2010, accessed 8 May 2010.

[11] Ibid.

[12] Yergin, *The Prize*, 383.

[13] “The Impacts of Synfuels (GTL, CTL, BTL, OTL) on World Petroleum Supply,” briefing by Zeus Development Corporation, n.d., slide 11 (in notes), available from www.eia.doe.gov/oiaf/aeo/conf; Internet; accessed 20 December 2009. “GTL compared to CTL: No coal handling, no reactor, no ash handling, no CO2 issues, it is at least 60% cheaper than CTL.”

[14] J.F. Shultz et al, “Prepoisoning of Iron Catalysts by Sulfur Compounds,” *Studies of Fischer-Tropsch Synthesis* (March 1962), 501, available from http://pubs.acs.org/doi/abs/10.1021/j100809a030; Internet; accessed 8 May 2010.

[15]Joseph Hilyard, ed., *International Petroleum Encyclopedia 2005*, (Tulsa, OK: Pennwell Corporation, 2005), 345. For data prior to 1950: Frank W. Millerd, “Global Oil Production,” in *The New Global Oil Market: Understanding Energy Issues in the World Economy*, ed. Siamack Shojai (Westport, CT: Praeger Publishers, 1995), 18.

[16] Yergin, *The Prize*, 154-155. Using fuel oil system provided significant advantage over coal burning steam propulsion. Oil has a greater energy density, vastly simplified refueling arrangements, requires no stokers, emits much less smoke to obscure gun laying, and makes the ships less visible on the horizon. With then-current technology, it immediately provided 3 knots of additional speed, allowed travel over twice the distance between refueling stops, and eliminated the storage room and personnel (coal stokers) needed for coal. Fuel oil propulsion systems were fitted on the British *Queen Elizabeth Class Fast Battleships* in time for the famous Battle of Jutland in 1915.

[17] Ibid., 323-324. This, following the U.S. oil embargo to Japan (and other events which escalated tensions). In 1940, the Dutch East Indies produced a comparable amount of oil to that of the Mideast. Also see, Haruko Taya Cook and Theodore F. Cook, *Japan at War* (New York, NY: W.W. Norton Company, 1992), 24.

[18] James D. Hamilton, *Oil and the Macroeconomy*, Department of Economics, University of California at San Diego (August 2005), Table 1, 11, http://dss.ucsd.edu/~jhamilto/JDH_palgrave_oil.pdf, accessed 15 June 2006. Also, Lowell S. Feld, "Oil Markets in Crisis: Major Oil Supply Disruptions Since 1973," in *The New Global Oil Market: Understanding Energy Issues in the World Economy*, ed. Siamack Shojai (Westport, CT: Praeger Publishers, 1995), 105-111.

[19] Joseph Hilyard, ed., *International Petroleum Encyclopedia 2008*, Table 6, World Oil Imports and Exports (Tulsa, OK: Pennwell Corporation, 2008), 417.

[20] Andrea Burgess, el al, "World in Figures," *The Economist*, 2008 Pocket Edition, 26, 56. There is a direct correlation between GDP and petroleum consumption. In 2008, eight of the ten largest economies in the world were also in the top 10 consumers of petroleum. The two outliers, Italy and Spain, were number 12 and 16 respectively.

[21] Gates, *NDS*, 16. "The United States requires freedom of action in the global commons and strategic access to important regions of the world to meet our national security needs. The well-being of the global economy is contingent on ready access to energy resources. Notwithstanding national efforts to reduce dependence on oil, current trends indicate an increasing reliance on petroleum products from areas of instability in the coming years, not reduced reliance. The United States will continue to foster access to and flow of energy resources vital to the world economy. Further, the Department is examining its own energy demands and is taking action to reduce fuel demand where it will not negatively affect operational capability. Such effort will reduce DOD fuel costs and assist wider U.S. Government energy security and environmental objectives."

[22] President George W. Bush, *The National Security Strategy of the United States of America* (Washington, DC: The White House, 2006) 28.

[23] *World Oil Transit Chokepoints,* Energy Information Administration, U.S. Department of Energy, available from http://www.eia.doe.gov/cabs/World_Oil_Transit_Chokepoints/Background.html; Internet; accessed 8 January 2008.

[24] Hilyard, *Petroleum Encyclopedia 2008*, Table 6, 417.

[25] Ibid., 170-176, 187. Iran has proved reserves of 948 tcf. Qatar has proved reserves of 905 tcf. They are 2nd and 3rd largest *conventional* natural gas reserves in the world. Russia is 1st with 1,680 tcf.

[26] Ibid., 187-188.

[27] Ibid., 188. Projected output for *Oryx* is approximately 68,000 bpd, and *Pearl* is projected to exceed 250,000 bpd of combined fuel and other distillates. Also see: Oryx GTL website, available from http:// www.oryxgtl.com/English/index.html; Internet; and Royal Dutch Shell PLC news website, available from http://royaldutchshellplc.com/tag/pearl-gtl-project/.

[28] Hamilton, 11. Following the 1973 Arab oil embargo, the GDP of the U.S. economy dropped 3.2%.

[29] "Oil Prices Hit $147 Over Iran Threats," *Gulf Daily News*, 12 July 2007, World News Network online service; available from http://article.wn.com/view/2008/07/12/Oil_prices_hit_147_over_iran_threats/?section=Business&template=worldnews%2Findex.txt; Internet; accessed 2 May 2010.

[30] James J. Carafano et al, "If Iran Provokes an Energy Crisis: Modeling the Problem in a War Game," Heritage Center for Data Analysis, CDA07-03 (Washington, DC: Heritage Foundation, 25 July 2007) 10 pages; and William Beach et al, "The Global Response to a Terror Generated Energy Crisis," Heritage Center for Data Analysis, CDA08-11 (Washington, DC: Heritage Foundation, 10 November 2008), 14 pages.

[31] Carafano et al, "If Iran Provokes an Energy Crisis", 1.

[32] Carafano et al, "If Iran Provokes an Energy Crisis", 5; and Beach et al, "The Global Response," 11.

[33] Bureau of Economic Analysis, U.S. Department of Commerce website, available from http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=6&Freq=Qtr&FirstYear=2006&LastYear=2008; Internet; accessed 22 May 2010. United States GDP 2007 4thQ: $13,391.2; 2008 4thQ: $13,141.9. This is a GDP loss of $249.3 billion.

[34] *IEA Response System for Oil Supply Emergencies*, International Energy Agency homepage, available from http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=1912; Internet; accessed 5 May 2010. The IEA was formed in 1974 following the Arab Oil Embargo of 1973. The IEA was formed by 17 member nations of the Organization for Economic Cooperation and Development (OECD) as a balance to Organization of Petroleum Exporting Countries (OPEC). The IEA now has 28 member nations and requires each member to maintain an emergency petroleum reserve of at least 90 days supply to absorb shocks and disruptions to global petroleum supply.

[35] Charles King, "The Five Day War: Managing Moscow after the Georgia Crisis," *Foreign Affairs* 87, no. 6 (November/December 2008), 7. Coincidentally, Georgia is the transit nation of the BTC pipeline, the only oil pipeline coming from Asia into Europe that Russia does not yet control.

[36] Hilyard, *Petroleum Encyclopedia 2008*, Table 3, 410.

[37] *Weekly Petroleum Navigator: Brent Blend Spot Price*, Energy Information Agency website available from http://tonto.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WEPCBRENT&f=W; Internet; accessed 5 May 2010. The first week of July 2008 Brent crude hit $142.45 per barrel.

[38] John Deutch and James Schlesinger, *National Security Consequences of U.S. Oil Dependency* (New York, NY: Council on Foreign Relations, 2006) 26-30.

[39] "The Drum Beat," *The Oil Drum* industry website, discussion from December 2006, available from http://www.theoildrum.com/story/2006/12/3/95919/8889; Internet; accessed 5 May 2010. Also see Matthew R Simmons, *Twilight in the Desert: The Coming oil Shock and the World Economy* (Hoboken, NJ: John Wiley & Sons, 2005), 422 pages. According to "The Drum Beat," estimated cost to produce a barrel of Saudi crude in 2006:

Capital Costs/bbl $19

Operating Costs/bbl $10
Estimated Royalty/bbl $25 (This royalty estimate subsidizes most costs of the Saudi Kingdom)
Estimated Cost/bbl $54 (The Saudis like to keep oil above $65/bbl)
At 8.5 mbpd and oil at $80/bbl, Saudi Aramco is making slightly more than $1.5 billion per week of net profit. At $100/bbl, net profit exceeds $2.5 billion per week.

[40] *Top World Net Exporters*, Energy Information Administration, U.S. Department of Energy, available from http://tonto.eia.doe.gov/country/index.cfm; Internet; accessed 5 May 2010.

[41] Daniel Yergin, "Energy Security and Markets," in *Energy and Security: Towards a New Foreign Policy Strategy*, eds. Jan H. Kalicki and David L Goldwyn (Washington, DC: Woodrow Wilson Center Press, 2005), 55-57. Daniel Yergin authored Pulitzer Prize winning book *The Prize: The Epic Quest for Oil, Money and Power*, which then was made into a PBS series for television. Yergin is Chairman of Cambridge Energy and Research Associates, available at www.cera.com.

Yergin's Ten Principles are included for the reader's edification:

1. Diversification of supply is the main guarantor and starting point for energy security.
2. Policymakers must recognize that there is one global energy market, and U.S. energy security resides in the stability of this market.
3. Security requires a "security margin" consisting of global spare capacity and a national strategic petroleum reserve.
4. Government intervention into energy markets can be highly counterproductive, hindering the system from swiftly shifting supplies around to adjust for disruptions in supply.
5. Build cooperative relationships with nations that produce and export energy.
6. Build cooperative relationships with other importing nations.
7. Increased interdependence requires a proactive security framework.
8. When markets become tight or disrupted it is important for governments and the private sector to provide good quality information to calm public fears, and thus avoid poor policy decisions.
9. A healthy, technologically driven , energy industry is necessary for energy security.
10. A commitment to research and development and innovation across a broad spectrum is fundamental to energy security.

[42] Gene Whitney, Carl E. Behrens, and Carol Glover, "U.S. Fossil Fuel Resources: Terminology, Reporting, and Summary," *CRS Report for Congress,* R40872, Table 5 (Washington, DC: Congressional Research Service, Library of Congress, 30 October 2009), 17.

[43] Whitney, "U.S. Fossil Fuel Reserves," 17. Graph from: Robert P. Smith, *Energy: Present and Future*, 2nd ed. (Strategic Energy Resources: Oklahoma City, OK, 2009), 35.

[44] In 2000 U.S. proved reserves were 177 trillion cubic feet (tcf). In 2009 U.S. proved reserves were nearly 250 tcf. *U.S. Dry Natural Gas Proved Reserves*, Energy Information Administration, U.S. Department of Energy, available from http://tonto.eia.doe.gov/dnav/ng/hist/rngr11nus_1a.htm; Internet; accessed 1 May 2010.

[45] Whitney, "U.S. Fossil Reserves," 11-12.

[46] "Energy: Project Realism," *Time*, 2 September 1974 [magazine on-line]; available from http://www.time.com/time/magazine/article/0,9171,943755,00.html; Internet; accessed 7 May 2010. Also see "Energy Timeline from 1971-1980," *Department of Energy Home Page*, available from http://www. energy.gov/about/timeline1971-1980.htm; Internet; accessed 7 May 2010. In 1973 President Richard Nixon launched *Operation Independence* to achieve energy independence by 1980.

[47] Ibid.

[48] Dr. Theodore K. Barna, "OSD Assured Fuels Initiative," briefing with slides, *2006 Aerospace in the News, Executive Symposium*, slide 16, available from http://www.oilcrisis.com/coal/ctl/ EnergyOSDAssuredFuel2006HarrisonBarna.pdf; Internet; accessed 4 May 2010.

[49] Bush, *NSS*, 28.

[50] Gates, *NDS*, 16.

[51] Tim Edwards, "DOD/AF Assured Fuels Initiative Update," briefing with slides, *Air Force Research Laboratory* (30 July 2007), slide 6, available from http://www.cffs.uky.edu/Energy/meetings/ 2007%20Meeting/Mon%20AM/AFRL%20Edwards.pdf; Internet; accessed 25 April 2010.

[52] Mark Woodbury, "B-52 Tests Alternative Jet Engine Fuel," *U.S. Air Force News Website*, 19 September 2006, available from http://www.af.mil/news/story.asp?id=123027415; Internet; accessed 6 May 2010.

[53] Ibid., slides 9-15.

[54] James Hileman et al, *Near-Term Feasibility of Alternative Jet Fuels* (Santa Monica, CA: Rand Corporation, 2009), 42-46, available online from http://www.rand.org/pubs/technical_reports/ 2009/RAND_TR554.pdf; Internet; accessed 22 April 2010. Prices vary greatly depending on price of feed stock (gas, coal and biomass), size and scale of production capacity, etc. GTL fuels could be produced at $1.60 to $1.92 per gallon, and CTL/BTL fuels could be produced at $1.99 to $2.34 per gallon.

[55] Anthony Andrews, "Department of Defense Fuel Spending, Supply Acquisition, and Policy," *CRS Report for Congress,* R40459 (Washington, DC: Congressional Research Service, Library of Congress, 22 September 2009), 19.

[56] Ibid.

[57] Ibid. "The Air Force has abandoned plans to attract private investment in a CTL fuel plant to supply Malmstrom Air Force Base, Montana, but DESC is interested in pursuing a pilot program for synthetic fuels [GTL] to support DOD JP-8 fuel requirements in Alaska."

[58] CO_2 is simply carbon's oxidized form. It is not a pollutant, nor a contaminant. It is as essential to life on earth as water, which in aerosol form is also considered a greenhouse gas (i.e. clouds). Regulating CO_2 makes about as much sense as regulating clouds, but that point is

beyond the scope of this work. Author's experience and observation as an energy and water policy consultant.

[59] Gary Roth, President, Syntroleum Corporation, transcript from investors conference call dated March 2, 2010, 2-3; available from http://www.faqs.org/sec-filings/100302/SYNTROLEUM-CORP_8-K/c97162exv99w1.htm; Internet; accessed 10 May, 2010. "We have completed removal of equipment from the Catoosa Demonstration Facility in accordance with our contract with Sinopec and have shipped all components to China."

[60] "China Readying Giant CTL Plant," *Upstream Online*, online news service, 4 June 2008, available from http://www.upstreamonline.com/live/article156260.ece; accessed 10 May 2010.

[61] Hileman et al, 120 pages.

[62] Lance A. Vann, *Feasibility of JP-8 to Jet-A Fuel Conversion at U.S. Military Facilities*, Thesis, Air Force Institute of Technology, March 2008, 17. "As noted earlier, the only significant difference between Jet A and JP-8 is the difference in freeze point. Jet A has a higher freeze point of -40ºC and
JP-8 has a more stringent freeze point of -47ºC."

[63] Hileman, 59-62.

[64] Hileman, 65.

[65] Ibid.

[66] Ibid., 69.

[67] Ibid. 64, 70-71, 84. The study assumed that natural gas prices would rise as demand for its historic uses increased (pg. 84). That has not been the case. Prices have been flat as U.S. supply increases continue to slightly outpace demand. The continued low price of natural gas makes it a more attractive option for F-T fuels.

[68] William J. Cox, President, Alchem Field Services, multiple discussions with author beginning in August 2006, Oklahoma City, OK. Alchem Field Services developed a skid-mounted GTL processor prototype that could be transported by truck. Alchem was later acquired by Waste Management, Incorporated.

[69] Kim J. Huntley, Director, Defense Logistics Agency, letter and attachments to Senator James Inhofe, 21 October 2009, Tab 1, Page 1. Total consumption of Jet Fuel for all U.S. military installations in 2008 was 2,422,088,441 gallons.

[70] *Company Overview, Rentech Homepage*, available from http://www.rentechinc.com/companyOverview.php; Internet; accessed 20 December 2009.

[71] *Rentech Homepage.* The 30,000 bpd facility is a BTL facility. Also see *Syntroleum Corporation Homepage at http://www.syntroleum.com/proj_rba_bio-synfining.aspx*. Syntroleum's 5,000 bpd Bio-synfining™ is also a BTL facility. Both receive tax credits of $.50 per gallon of production.

[72] "Pearl Gas-to-Liquids Project, Ras Laffan, Qatar," *Hydrocarbons-Technology.com*, n.d., Net Resources International online industry news service, available from http://www.hydrocarbons-technology.com/projects/pearl/; Internet; accessed 11 May 2010.

[73] Huntley, DLA Letter to Inhofe.

[74] Ken Agee, interview by author, 30 November 2009. Ken Agee is the founder of Syntroleum Corporation, and the current President of Emerging Fuels Technology. Mr. Agee expressed a caveat that the exact costs to construct a GTL facility at each Air Force Base would vary depending upon many cost factors. Once the first facility is designed and built, costs for each similarly designed facility go down.
Mr. Agee confirmed that ten GTL facilities with output of 1,000 bpd for $500 million is a reasonable approximation. A more precise figure would require engineering study of each prospective site. For instance, Hickman AFB might be more expensive due to transportation costs to Hawaii. But then, Hickman might not be a good place for a GTL facility anyway, since Hawaii has no natural gas wells and all natural gas must be brought by LNG tanker. Another base with lower costs and direct access to gas might make more sense.

[75] Kristine E. Blackwell, "The Department of Defense: Reducing its Reliance on Fossil-Based Aviation Fuel – Issues for Congress," *CRS Report for Congress,* RL34062 (Washington, DC: Congressional Research Service, Library of Congress, 15 June 2007), 13-14.

[76] Ibid.